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Transforming agribusiness in developing countries: SDGs and the role of FinTech

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Transformation of agribusiness is critical in light of the Agenda for Sustainable Development. FinTech and the integration of FinTech with other (green) technologies as well as with digitized agriculture plays an important role when it comes to, for example, SDG 12, specifically, responsible production, as it can mitigate trade-offs and enhance synergies between environmental and social SDGs, for example, 1 and 15, increasing profitability without additional use of natural resources. Important limitations and risks need to be addressed, however, for developing countries to fully benefit from the potential that FinTech holds in this context. Mitigating factors include massive infrastructure investments and large-scale capacity building. Rigorous research on economic sustainability and cost-effectiveness of newer FinTech models is needed to make sound policy recommendations.

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Introduction

The U.N. General Assembly's adoption of the 2030 Agenda for Sustainable Development (ASD) [1] identified sustainability as the core guiding principle for development efforts at every level, from local to global. The ASD comprises 17 sustainable development goals (SDGs) that specify targets and indicators for achieving social and environmental sustainability, with simultaneous considerations of economic sustainability, across multiple themes of development.

Decisive progress toward the SDGs will require transformative changes of food and fiber value chains [2,3]. Notably, agribusiness has enormous impact on SDGs pertaining to social sustainability (e.g. 1 – no poverty, 2 – zero hunger, and 10 – reduced inequalities) as well as environmental sustainability (e.g. 13 – climate action and 15 – life on land): it is responsible for the economic status of the majority of the world's poor [4] and provides food, feed, other consumption goods, and industry inputs. Agribusiness occupies over 40 percent of the earth's land surface [5] and is responsible for about $^{1}/_{4}$ of annual greenhouse gas emissions [6].

Trade-offs may arise between the transformation of the sector in line with one SDG and another [7], as exemplified by the potential trade-off between increased food production and terrestrial ecosystem protection [8]. Consider, for example, an agribusiness model based on mass production with intensive use of large tracts of land: An expansion in cropland and the accompanying additional agricultural water withdrawal for irrigation will result in improved food security (SDG 2, see Ref. [9]) but weaken biodiversity conservation (SDG 15, see Ref. [10]) and severely threaten freshwater ecosystems (SDG 6 – clean water and sanitation, see Ref. [11]). However, the *extent* of such trade-offs is context dependent [12]. Decoupling economic progress in the context of agribusiness from natural resource use in line with SDG 12 (responsible consumption and production) and, more generally, transforming agribusiness according to a coherent, unified approach toward *all* SDGs that mitigates trade-offs and enhances synergies thus represents, in light of the ASD, one of *the* most critical challenges of our times.

Key mitigating factors prominently include *technology* [7]: In particular, recent innovations in FinTech—an emerging industry that uses technology to provide and facilitate financial services [13], with financial intermediation services delivered through mobile phones, computing devices using the internet, or cards linked to secure digital payment systems [14] – and the integration of FinTech with other (green) technologies and advanced applications of data science in agriculture, have shown immense potential in this regard. Throughout section two we provide several examples of how trade-offs of the nature mentioned in the preceding paragraph can be mitigated using FinTech in combination with other (green) technologies.

Besides that, and more generally speaking, FinTech offers new ways of expanding in a responsible manner the inclusion of the financially excluded – small-holders, as well as small-sized and medium-sized enterprises – into the folds of financial system by providing them with a wider range of financial services and products, and turning them into generators of assets [15]. Thus, FinTech is a key frontier in the expansion of the practice of inclusive business. This expansion is mainly facilitated by innovation through the introduction of, for example [16]: distribution channels that can encompass sparse customer bases spread over difficult-to-access rural geography; cost-reductions achieved through economies of scale and/or more efficient operations enabling profitable inclusion of low-margin customers; and last but not least, new, low-cost products or services that meet the needs of previously underserved or excluded populations.

This review synthesizes recent literature pertaining to FinTech in the context of agribusiness in developing countries, focusing on the post 2016 period. It outlines impact pathways from FinTech to SDGs, drawing on examples from sub-Saharan Africa, and argues whether and how the potential benefits of FinTech for supporting SDGs while mitigating trade-offs across the pillars of sustainability can be realized, and under which conditions this is most likely. It also highlights limitations and possible risks in this endeavor.

In all of that, the discussion is centered around mobile money and mobile financial services,[4] as these are the most widely adopted forms of FinTech in rural sub-Saharan Africa and have been interlinked with many other technologies as well as digitized agricultural systems.

FinTech and agribusiness

The discussion in this section is centered around mobile money and mobile financial services. These terms are not meant to exclude digital payments and digital finance from the discussion. While a systematic distinction between the terms – that are often used interchangeably in the literature, with 'digital', however, referring to the end user requiring access to digital devices (as opposed to a simple text-based mobile phone) – can be useful, as generally speaking access to the internet enhances possibilities [17••], we instead explicitly mention the role of the internet wherever access is critical, as most of the services outlined below (or at least some equivalents) are accessible without internet. This point has to be evaluated positively in terms of accessibility.

Mobile money

Initially, mobile money platforms (MMPs) and associated mobile wallet technologies, which enable electronic transactions via mobile phone, were designed for person-to-person (P2P) money transfers [18••], offering the potential for wide accessibility [19]. Mobile money has been among the most rapidly adopted innovations throughout the world [18••]. This rapid, wide adoption is supported by the proliferation of mobile phones, as well as the speed, flexibility, convenience, and affordability associated with mobile money usage [20,21].

A key application of mobile money is the sending and receiving of remittances. Currently, roughly a quarter of unbanked adults in sub-Saharan Africa remit funds utilizing cash or OTC services [17••]. Mobile money P2P transfers have emerged as an alternative with the caveat that OTC services still outperform mobile money services in terms of cost-effectiveness in much of sub-Saharan Africa; yet, the sending and receiving of remittances has become the main use of mobile money in sub-Saharan Africa [17••]. Mobile money can thus serve as a critical conduit for financing for smallholder farmers and lead to increased investment in agribusiness. Impacts on environmental sustainability are, however, ambiguous as productivity gains may not be achieved in environmentally friendly ways.

Mobile financial services

As the scope of MMPs expanded, users became able to use them for making deposits, withdrawals, making person-to-business payments, paying taxes, receiving payments from businesses and governments, saving, lending, borrowing, taking out insurance and making investments [18••,20],[5] leading to wide-spread inclusion of the unbanked into the financial system [22,23]. The provision of these services may have positive effects on health (SDG 3), employment (SDG 8), education (SDG 4), and poverty alleviation (SDG 1) through increased productivity ([21,24]). As noted earlier in the context of MMPs, though, the impact on environmental sustainability may be ambiguous. However, initiatives that integrate mobile financial services with other (green) technologies (sub-section 'Digital crop insurance'), as well as interoperability between MMPs, monitoring technology, and big data platforms (possibly interacting with digitized agricultural systems) (sub-section 'Data science, FinTech, and the SDGs'), hold enormous potential to enhance synergies between the pillars of sustainability.

[4] Other promising FinTech applications include distributed ledger technology (blockchains), which can interact with the Internet of Things (IoT) to improve system orchestration, monitor social and environmental responsibility or provenance information in agricultural supply chains (e.g. trace produce to improve social and environmental accountability; [56]), lower transaction costs, ease financing and mobile payments, and generally smooth the management of supply chains while maintaining integrity and security.

[5] Reminders and other nudges, for example in form of text or in-app messages, are often employed as cost-effective ways to help customers meet self-determined goals, increase savings and support loan repayment ([57]).

Integration of mobile financial services with other (Green) technologies

A number of initiatives integrate mobile financial services with other (green) technologies. In 'Solar panels' and 'Digital crop insurance' we give two examples.

Solar panels

One example of the aforementioned initiatives is the provision of payment plans for green technologies. A particularly interesting initiative in light of SDGs 7 (affordable and clean energy) and 13 allows households that lack access to electric grids to use mobile money accounts to finance pay-as-you-go solar-powered energy. Especially in sub-Saharan Africa, where almost 600 million people lack access to electricity [25], these initiatives are promising, also in terms of increasing agribusiness efficiency in line with SDG 12, as monitoring (e.g. ground sensors) and mechanization (e.g. irrigation) devices can be solar powered. Examples of such services include M-KOPA in Kenya and Fenix in Benin, Nigeria, Uganda, and Zambia that both offer digital financing plans for solar units.

Digital crop insurance

FinTech helps poor farmers build resilience to weather-related shocks, which is increasingly important as agriculture suffers from the effects of climate change [26••]. Greater resilience can be achieved through climate-smart agriculture (CSA), which entails stress-tolerant seed varieties [27]. However, many farmers have lost trust in improved seeds [28,29] and invest *only in the presence of* an affordable, high-quality insurance system [30].

Digital FinTech can help increase the adoption of available index insurance by integrating innovations in the data infrastructure to improve the correlation of index insurance payouts with actual damage. Such innovations include remote satellite sensing (e.g. [31,32]) and picture-based monitoring of crop health—a cost-effective option that combines smartphone technology with digital payment features to ensure that farmers receive insurance payouts if digital pictures show damage on insured plots [33,34]. In describing an experiment in India, Hufkens *et al.* [35•] propose that smartphone-based near-surface remote sensing is superior to alternatives like satellite remote sensing when it comes to capturing the progression of crop growth.

FinTech which encourages the adoption of insurance against weather shocks[6] thus transforms agriculture in line with SDGs 1, 2, and 10 but also 12, 13, and 15 by inducing farmers to engage in CSA (e.g. [27,36,37]). FinTech is thus the first link in a chain which can lead to greater adoption of CSA, increased resilience as a result, and consequently, higher profitability, which in turn leads to greater access to FinTech—increasing agricultural output without necessarily using additional natural resources.

[6] Smartphone technology also enables the development of comprehensive packages, such as those that bundle credit and savings opportunities with insurance, access to improved seeds, and advisory services, to improve smallholders' resilience to weather shocks.

Data science, FinTech, and the SDGs

The examples provided in sub-section 'Integration of mobile financial services with other (green) technologies' implicitly touched on the crucial role of data science in transforming agriculture in line with the SDGs. In this section, we elaborate on this role in the context of several recent FinTech applications centered around digital platforms, and point out how artificial intelligence (AI) and machine learning can greatly enhance the benefits of such integrated systems.

Digital market places

Farm-level information on digital platforms can be used to create digital marketplaces, a system design solution accessible via text-based mobile phones or digital devices that connects stakeholders and furthers social and environmental SDGs, for example, by reducing food waste. An example is The Digital Green Loop system which helps Indian farmers to connect with local entrepreneurs and transporters to sell produce to wholesalers, eliminating costly, time-consuming marketplace activities and reducing delays [38].

A particularly exciting example of a digital market place for *inputs* is Hello Tractor, operating in Kenya, Mozambique and Nigeria, besides several Asian countries [39]. Hello Tractor allows farmers to rent or buy smart tractors via a digital interface, in which farmers and owners of smart tractors can interact and transact.

Agronomic advice

Recent initiatives link technological innovations (often specific to agricultural contexts) to centralized digital platforms that can store and analyze data gathered from farmer surveys, aerial monitoring, and/or ground sensors. The outcome of such an analysis can be used by farmers to inform their decision-making, sometimes via direct feedback mechanisms but often via organizations that provide agronomic advice. For example, providing financial service providers access to such data platforms (via MMPs) helps mitigate the often severe problem of asymmetric information between them and smallholder farmers, opening up possibilities for increased access to credit as well as new insurance models, and, in turn, allowing and incentivizing these financial organizations to provide targeted agronomic advice to their clients.

An example includes a recent project in Uganda, where loans, market linkages and drought insurance are bundled together with weather tips and made available to farmers through text messages [40]. The system uses information collected by satellite systems and matches it with

information gleaned from traditional data sources to provide farmers with individualized agronomic advice.

AI, machine learning, and fully integrated digitized agricultural systems

When it comes to the interplay of various technologies within agricultural systems and the possible integration of such agricultural systems with MMPs, the degree of optimization of agricultural practices in line with SDG 12 – via the mechanisms and pathways described in sub-section 'Agronomic advice' – obviously depends on a number of parameters: the composition of stakeholders (notably, whether financial service providers are present); the exact nature of technologies employed; the degree to which these interact within the system; the level and speed of data analysis performed; as well as the mechanisms through which agronomic advice/feedback to the farmer is provided and implemented.[7] In short: to what degree large volumes of high quality data can be generated and used effectively by the various stakeholders.

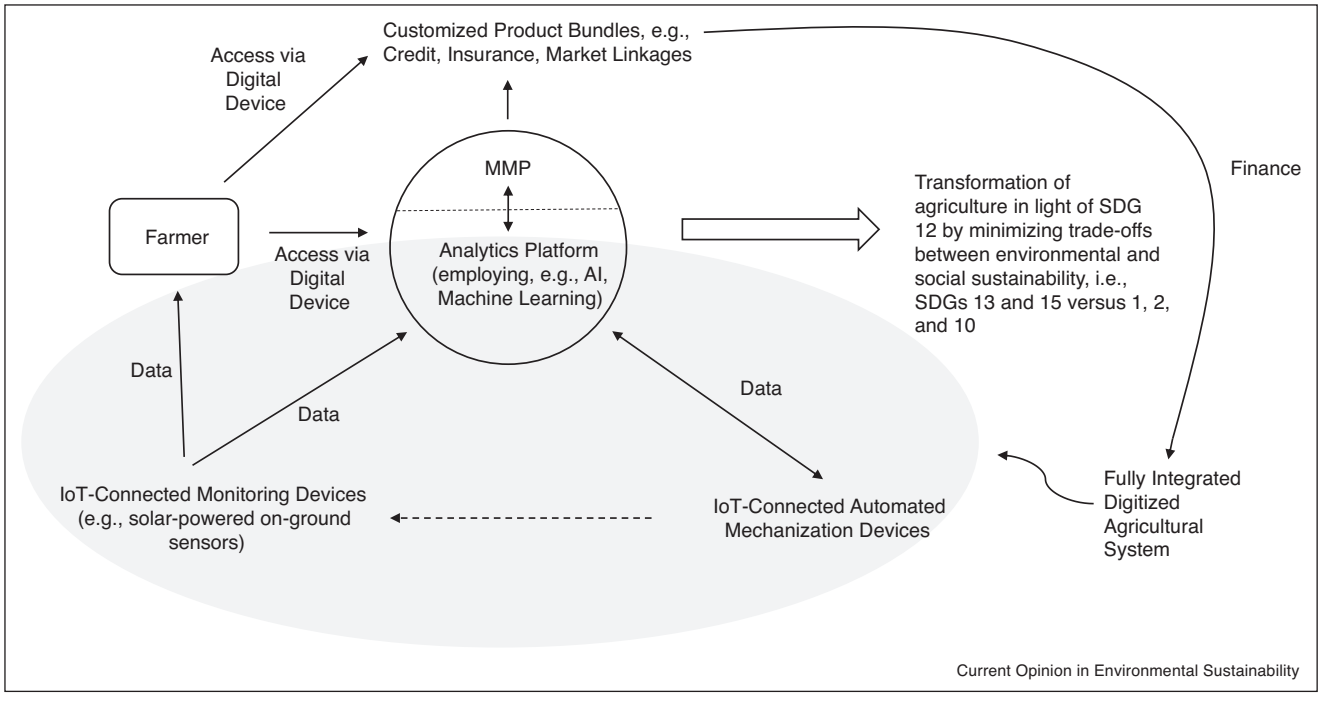
An example of a (close to) fully digitized agricultural system is the one provided by Illuminum Greenhouses in Kenya that combines solar-powered sensors, data analytics, and automated drip irrigation systems. Agronomic advice arrives on and can be implemented via text-based phone by the end user.

In their most advanced form, fully integrated digitized agricultural systems comprise data collection technologies such as in-ground or on-ground sensors connected to the Internet of Things (IoT), which upload data in real time to an analytics platform that employs AI and machine learning to provide prescriptive recommendations, which are in turn communicated to fully automated mechanization devices connected to the IoT [41•].

While such systems by themselves are able to increase productivity and save natural resources at the same time (e.g. lower water use), interoperability/synergies between MMPs and such systems (with mobile financial service providers being able to access a suitably defined subset of the data and customize product bundles in response, as outlined in sub-section 'Agronomic advice'), represent a true game changer in terms of transforming agriculture in light of SDG 12 by minimizing trade-offs between environmental and social sustainability, that is, SDGs 13 and 15 versus 1, 2, and 10. This is shown schematically in Figure 1 below.

For illustration purposes, one might think of a system that combines IoT-connected solar-powered sensors which upload crop-information in real time to a data analytics platform that employs AI and machine learning to inform automated drip irrigation systems, which are in turn also connected to the IoT. If financial service providers can glean information about crop conditions through MMPs being interconnected with the analytics platform, the problem of asymmetric information is mitigated, and access to credit and insurance products greatly increases.

Figure 1



Interoperability between MMPs and fully integrated digitized agricultural systems.

The pathway to relevant SDGs in this example is as follows: in line with SDG 12, the implementation of the agricultural system outlined in this example reduces water usage (compared to less sophisticated systems) by drip-watering plants exactly when and to the precise extent needed – thus enabling increases in agricultural output (SDGs 1, 2, and 10) without the necessity for farmland expansion (SDG 15). In addition, increased access to credit and insurance allows the farmer to invest into crop varieties that are more robust towards climate change (SDG 13), thus lowering the risk of crop-failure (once more, SDGs 1, 2, and 10).

Limitations and risks

Successful mobile money services, for example, M-Pesa in Kenya [42••], have encouraged a belief that FinTech can induce sustainable growth in poor, agrarian areas of sub-Saharan Africa. However, it should be kept in mind that past lessons learnt about the cost effectiveness of classic FinTech applications like mobile money cannot readily be applied to the future as new, unforeseen products are being introduced, contexts are changing, and the greater inclusivity that is aimed for implies that the characteristics of the customer base will be changing as well. Thus, existing empirical evidence might prove to have limited external validity and further research on economic sustainability and the cost-effectiveness of new FinTech products as well as classic FinTech products in new contexts is needed. With this caveat in mind, especially the recent extensions of classic mobile financial services discussed in sub-sections 'Integration of mobile financial services with other (green) technologies' and 'Data science, FinTech, and the SDGs' highlight the potential of FinTech to transform agribusiness in line with SDG 12. The following sub-sections discuss further limitations and risks in this process.

Infrastructure, investment, and regulation

In most sub-Saharan African countries, particularly the rural areas that host most agribusinesses, the lack of resources, distance to networks, and inadequate electrical or communications infrastructure limit the adoption of FinTech [21,43,44]. More broadly, implementing key aspects of the Paris Agreement would require an investment of US$3.3–4.5 trillion annually in critical SDG sectors in developing countries, yet funding gaps remain of about US$2.5 trillion annually [45], and in 2010–2014, only 0.33% of worldwide investments in FinTech took place in Africa [46].

There is evidence that overall rule of law [47] is critical in this respect. Common law environments have also been shown to be helpful ([43], finds that the adoption of FinTech is much higher in common law as opposed to civil law African nations, which might indicate that the superior protection against risk, for example, better investor protections, available under common law incentivizes investments in FinTech). Further, when designing an appropriate regulatory framework to promote adequate investment into FinTech, certain specific features of FinTech should be taken into account, for example, the fast pace of innovation and low entry-barriers [48]. While best practices regarding the design (process) have not yet been established [47], some key considerations and global trends have emerged. For one, regulators must carefully define their main objectives before tackling regulation as different goals are often at odds with one another, for example, boosting financial inclusion versus increasing competition [47]. In addition, when evaluating various approaches, special attention needs to be focused on cases that touch on critical socio-economic priorities (e.g. financial inclusion) or entail systemic risks. Generally speaking, a framework that allows sufficient flexibility and continuous, fast updates to regulation seems desirable [49].[8] Indeed, in Kenya and South Africa, the two leading centers of FinTech in sub-Saharan Africa, the governments took a piecemeal regulatory approach, without any *specific* legal framework for FinTech [47].

Overall, different sub-Saharan African governments have so far taken a variety of approaches to FinTech regulation, some 'hands-off', some 'wait and see', and others more forward-looking. In fact, it is possible that the more rigid regulatory approach taken by *some* sub-Saharan countries contributed to their relative lack of success in the promotion of FinTech compared to Kenya and South Africa.

Furthermore, taking into account local context and conditions is crucial. Revisiting the example of Kenya and South Africa in this context, the differences in local conditions between these two nations, and their consequences, make the best case for this approach: Kenya has a more comprehensive and inclusive end-to-end (supply to demand) ecosystem with extensive usage of apps, whereas South Africa is more advanced on the supply side and can be characterized as a vast technological hub that fosters design and creation of FinTech.[9] Indeed,

[7] For example, a farmer might review information gathered by sensors and make/implement decisions without the involvement of an analytics platform; or she might implement recommendations provided by an analytics platform using standard, as opposed to automated, mechanization devices.

[8] One way to promote FinTech in a flexible framework that has sparked great interest is to install regulatory sandboxes: young firms in nascent markets can be granted leeway in the form of waivers or modifications of rules, or official assurances of non-enforcement during an incubation period when they experiment with new products or services ([49]).

[9] We thank and paraphrase the comments of an anonymous referee who brought this to our attention.

intrinsically similar FinTech products have had vastly different experiences in terms of local demand in these two countries (e.g. the success of Safaricom's M-Pesa in Kenya, versus the relative failure of Vodacom's and MTN's mobile money platforms in South Africa). In summary, local context must inform the design of regulation and there is no 'one size fits all'.

In addition, peer regulation and market discipline can act as reinforcing tools for official regulation. Peer regulation brings with it the desired flexibility as it is able to accommodate, under the same regulatory umbrella, a large range of context-specific standards [50], with the caveat that it should only be given a notable role in the regulation of FinTech products that do not pose considerable risks to end users. Peer regulation in FinTech may take the form of a ratings system for a product or service substituting for official regulations of the same [49]. Such a system, for example, exists for the digital marketplace Hello Tractor mentioned in sub-section 'Digital market places'. Generally, while peer regulation can in principle be a cost-effective and democratic means of putting checks and balances in a rapidly evolving environment where standardization is inherently difficult [50], hard empirical evidence about its efficacy is currently lacking.

Turning to the potential role of market discipline in aiding official regulation, the situation is not always as clear-cut in the case of FinTech since non-market forces might be prominent, at least in the initial stages, for example, the government might give FinTech preferential treatment, or FinTech products might be introduced in an environment where they are subsidized by development organizations.

Overall, the discussions surrounding official regulation, as well as the role of peer regulation and market discipline in the context of FinTech make it clear that more research is needed from a number of different perspectives.[10] Of note, multiple universities and academic institutions in Africa – in cooperation with other organizations—have initiated FinTech incubators and accelerators, and their increased involvement in impact evaluations/other policy-relevant analyses would be extremely valuable.

Digital divides

Even if FinTech is widely promoted, it can ensure and promote inclusive growth only if it is adopted and used by disadvantaged groups, including smallholders. In developing countries, smallholders often are first-time users of FinTech and may have low general [17••] and digital [21,51] literacy, which limits their take-up and use of mobile financial services [52]. Nielsen [51] laments digitalization divides: FinTech innovations in developed countries separate end users from the design and development process, creating 'design–actuality gaps'. Another divide occurs due to differences in the socio-economic status of developers and end users such that digital technologies are rarely tailored to their particular needs. More empirical evidence about these digitalization divides and the assistance required by illiterate and poor end users to span them is needed.

There is also an emerging risk of a new form of inequality, with entire geographic areas and populations (partially) excluded from new technologies, and the new world of data and information. Such inequalities can stem from human capital differences: The success of particular forms of FinTech, especially if big data are involved, crucially depends on the availability of skilled labor, for example, data scientists. However, when it comes to data science, large and imminent human-capital shortages are predicted to increase drastically worldwide [53], including in Africa. In this particular case, shortages in developed countries are likely to lead to 'brain-drain' in the developing world, further exacerbating the situation in sub-Saharan Africa. While local initiatives (e.g. http://www.datascienceafrica.org/) and outsourcing of data science to other regions are helpful, more actions – in terms of local and foreign-aided capacity building measures – are urgently needed to mitigate these divides. Furthermore, SDG 10 can be undermined in a most severe form if providers decide to discontinue provisions of specific FinTech services to poor rural communities to save costs [54].

Issues in data ethics

In all of this, multiple issues surrounding data ethics pose a serious risk. These include respect for data sovereignty and data privacy, which call for proper data protection measures to be put in place. In particular, for mobile wallet technology, issues related to security and identity fraud are key impediments. A promising solution is biometric identification using, for example, fingerprint or iris scanners. An example of successful implementation of biometric identification is the eWallet system in Nigeria, where the government allocated vouchers to mobile wallets (eWallets) of farmers, which could then be used to obtain improved inputs from agro-dealers (see https://cellulant.com/blog/agritech-in-africa-how-an-e-wallet-solution-powered-nigeria-governments-ges-scheme/).

While it is likely that biometric identification technology reduces fraud enormously, rigorous research on its efficiency and scalability from a cost/benefit perspective is scarce. Available evidence [55] paints a mixed picture, with high rollout costs and heterogeneous effects across borrower types (fingerprinting increased repayment rates for high-risk borrowers only).

[10] The regulatory sandboxes mentioned earlier may in fact provide near-ideal conditions to conduct rigorous evaluations of different approaches to regulation.

Do green technologies affect the limitations of FinTech?
An interesting question that arises is whether there are differences, in terms of their limitations, between FinTech in general and FinTech used in combination with green technologies. On this issue, we think that most of the limitations that we outlined in section 'Limitations and risks' naturally apply both, for example, the issue of data ethics. However, certain points may apply differently to FinTech that is combined with green technologies. For example, it is conceivable that certain types of investors, like those interested in the so-called 'triple bottom-line', may be more willing to invest their funds in the latter. FinTech that is used in combination with green technologies might also be more conducive to inclusive business, for example, FinTech that includes solar panels may be accessible to those unconnected to electricity grids (see sub-section 'Solar panels'). Similarly, the presence of green technology on the supply side may encourage consumer demand of the agricultural product as well. However, our reading of the literature suggests that there is no clear verdict yet on the differences between FinTech in general and FinTech used in combination with green technologies in terms of their risks and limitations, mainly due to the paucity, at this point in time, of rigorous impact studies.

Conclusion

New sources of data, (green) technologies, and analytical approaches in combination with mobile financial services can create a digital ecosystem, in which tackling the transformation of agribusiness in developing countries in line with the ASD seems more possible than ever. Also, the limited hard empirical evidence on the efficacy of classic FinTech technologies such as mobile money, gives reason for hope.

Yet our review also uncovers serious limitations and risks such as: underinvestment in infrastructure, including physical capital, constraining access and implementation; shortages of human capital that, together with the previous point, may lead to divergence across the agribusiness sectors in developing and industrialized nations; and 'digital divides' as well as existent competing lower-cost products, such as OTC services in the case of remittances, constraining the adoption of FinTech. These are clear impediments in the path towards complete financial inclusion and the transformation of the agribusiness sector in line with SDG 12. Our review further shows that several conditions need to be fulfilled for these risks to be sufficiently mitigated. Perhaps most importantly to our readers, we identify a 'knowledge gap' in our current understanding of the cost, benefits and scalability of these technologies due to a lack of rigorous research on these issues as well as possible limitations in external validity of older studies due to changing end users and context, all of which limit the usefulness of predicting the trajectory of their applications and impact on inclusive business. We thus hope that this review will spur researchers to take heed of these gaps and try to answer some of the questions raised to aid fact-based policy formulation towards promoting inclusive business by realizing the SDGs in the agribusiness sector in developing countries.

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Conflict of interest statement

Nothing declared.

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Papers of particular interest, published within the period of review, have been highlighted as:

- • of special interest
- •• of outstanding interest

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